INDUSTRIAL HYGIENE SECTION

This Industrial Hygiene Section is published to promote sound thought upon and concerning industrial hygiene. To that end it will contain articles, discussions, news items, reports, digests, and other presentations, together with editorial comments. The editorial policy is to encourage frank discussion. On this basis contributions are invited.

Industrial Medicine

Reg. U. S. Pat. Off.

The Editorial Committee will exercise its best judgment in selecting for publication the material which presents most exactly the factors affecting industrial health and developments for control of potentially injurious exposures. The editors may not concur in opinions expressed by the authors but will endeavor to assure authenticity of fact.

The Science, the Law and the Economics of Industrial Health

Volume 5 October, 1944 Section 4

The Industrial Hygienist

—In the War Effort—

TNT spells disaster to the enemy but it can also spell trouble at home, in the production of the huge quantities necessary for modern warfare. In the last war much TNT was produced, and many of those engaged in its preparation were knocked out through being poisoned by TNT vapors and fumes. In the present war the tonnages of this substance are tremendously greater. The methods followed in its manufacture and handling are not radically different from those utilized in 1917 and '18, but, under present operating conditions, a new influence has been injected into this wartime industry, and, rather than a proportionately increased number of cases of TNT poisoning—as might normally be expected with attendant interruptions in production and difficulties with labor supply even under the stimulation of patriotic appeal—the facts are that cases of systemic TNT poisoning are almost nil.

How was this accomplished? What is this new influence which has markedly assisted in bringing about this most desirable but often difficultly obtainable achievement?

In TNT production and throughout the whole gamut of industry essential to the war effort, the industrial hygienist has been effectively engaged in determining those unit operations which may be causing exposures injurious to health and showing the way for control of such hazardous operations.

Freedom from injurious effects of the increasing number and variety of potentially injurious materials does not just happen; it must be accomplished through the application of the scientific methods which the industrial hygienist has developed and adopted over the last score of years.

During the more recent period, when production has been so important and trained labor so scarce, the work of the industrial hygienist has gone even farther as a contribution to the war effort than prevention of occupational diseases themselves. The presence of a condition in an industrial plant producing critical material of hazardous conditions which may send one or two workers to the hospital causes great apprehension among the remainder of the workers. Through the control of such hazardous conditions, hysteria among the workers is relieved—not only because the operations are causing no demonstrable injury but also because the workers feel more secure when they know that an experienced industrial hygienist is keeping in constant contact with potential health hazards so that they can be corrected, if necessary, before actual injury to health occurs.

Over the past decade, there has been a great expansion in the personnel and services of State Industrial Hygiene Divisions and in the Division of Industrial Hygiene of the U. S. Public Health Service. And during the war years, the Occupational Hygiene Branch of the U. S. War Department, Office of the Surgeon General, the Safety and Security Branch of the Office of the Chief of Ordnance, the larger yards of the U. S. Navy, and the U. S. Maritime Commission have all organized effective industrial hygiene programs to take care of conditions coming within their immediate jurisdictions. And the industrial hygiene divisions of a number of the leading insurance companies have extended their activities in occupational disease control in plants under their coverages.

A most encouraging development on the general front is the increasing introduction of industrial hygiene personnel, with field and laboratory equipment, among the industrial concerns of the country which, because of their size, have a variety of occupational disease exposures or, because of their type of activity, have some specialized industrial hygiene problem.

Recognition of the industrial hygienist throughout all the elements concerned with effective production, with an increasing emphasis on the necessity of controlling potential health hazards, speaks volumes on the values of results obtained. On the basis of the record of achievement for the war effort, the industrial hygienist can carry on with a new assurance that he is undertaking a work which not only he himself knows to be worth while but which management, medicine, labor, public health and all the elements making up the country's industrial and social organization have also recognized as being of such real value that they are counting on its continuance and progressive enhancement postwar. The industrial hygienist has demonstrated that he has served the country well in the war; he will do as well in peace.

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Soldering Operations

—Evaluation of Health Hazards in the Various Types of Soldering Operations, and Illustration of Practical Means of Control—

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ALTHOUGH soldering is one of the oldest industrial operations in use today, little can be learned about its associated health hazards in the industrial hygiene literature. This is reflected in the common disregard of the inherent hazards in soldering operations.

In order to fill this gap in the available information, the Industrial Hygiene Division began, three years ago, a survey of conditions at a variety of operations. Throughout this study the continuing conversion to war production and special war needs has emphasized the need for a better knowledge of methods for controlling the health hazards because of:

1. The tremendous increase in the volume of soldering operations;
2. Introduction of soldering into new industries;
3. Increased lead content of solders as a tin conserving measure, and other changes in composition of solders; and
4. Changes in soldering technique.

Definition

TO BEGIN with, the term soldering, as used in this paper, will apply to the joining of metal parts by means of a readily fusible alloy where the working temperature is well below the melting point of the parts to be joined. Also for this purpose, soldering will include "tinning"—the coating of metal by dipping into a bath of molten lead alloy. Related operations, such as brazing which merges into higher temperature hard soldering, and lead burning which is similar to some types of flame soldering, will not be included.

TABLE I.
COMPOSITION OF REPRESENTATIVE SOLDERS

Sn	Pb	Sb	Cd	Bi	Zn	Others	Melting Point °F.
Soft Solders							
63	37	....	....	....	....	....	361
50	50	....	....	....	....	....	421
40	60	....	....	....	....	....	460
33	67	....	....	....	....	....	485
15	85	....	....	....	....	....	545
38	60	2	....	....	....	....	442
49.25	50	0.75	....	....	....	....	406
50	25	....	25	....	....	....	320
66	27.5	....	6.5	....	....	....	342
50	32	....	18	....	....	....	295
50	25	....	....	25	....	....	266
20	40	....	....	40	....	....	235
37.5	....	....	12.5	50	....	....	151
30	....	....	50	....	20	....	531
50	....	25	25	....	....	....	592
50	25	....	....	....	25	....	637
37.3	62.7	....	....	....	....	.1 As	464
Tin Conserving Solders							
5	95	....	....	....	....	....	595
4	90	6	....	....	....	....	529
15	75	....	10	....	....	....	471
10	85	....	5	....	....	....	500
....	97.5	....	....	....	....	2.5 Ag	579
2	86	....	12	....	....	....	500
13	27	....	10	50	....	....	158
....	53.8	....	15.4	30.8	....	....	176
....	80	....	20	....	....	....	498
....	70	....	30	....	....	....	500
....	90	....	10	....	....	....	525
....	87	13	....	....	....	....	477
....	95	....	....	....	....	5 Ag	689
Hard Solders							
Ag	Cu	Zn	Cd	P	Sn	Others	Melting Point °F
50	34	16	....	....	....	....	690
50	16	16	18	....	....	....	627
30	38	32	....	....	....	....	745
15	80	....	....	5	....	....	640
63	30	7.5	....	....	....	....	.....
40	14	6	....	....	40	....	.....
....	....	75	20	....	....	5 Al	.....
80	13	6.8	....	....	....	....	.....
3	89	.25	.25	7	.25	.25 Co	.....

Presented at the Sixth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, St. Louis, May 11, 1944; available as Technical Paper No. 5, Illinois Department of Labor, Industrial Hygiene Unit.

Solders

SOLDERS are usually classified as "soft" and "hard" (see Table I) or "tin-lead" and "silver-copper alloys" respectively. The soft solders are worked at temperatures usually below 600°F, while hard solders generally require temperatures above 600°F.

The working temperature of most solders is always above their melting point. In the can industry the shift from solders of 30-40% lead content to the 98% lead-silver alloy has required an increase in the working temperature.[3] Fig. 1 illustrates the change in the melting point of solders as the lead content increases. Note that the melting point of 50% lead solder is only a little higher than that containing 30% lead. Although the lead-silver eutectic (97½% lead—2½% silver) melts at 580°F, in use these "98% lead" solders take up about 3% tin from the tin plate, and this reduces the melting point slightly. The higher working temperatures required by the new high-lead solders have necessitated changes in the heating technique, especially in the tin can industry.

From the standpoint of the health hazards the significance of the higher working temperatures is the much more rapid production of a surface of powdery oxide. However the increase in the vaporization of lead at higher working temperatures is practically negligible as shown by Fig. 2. It must be borne in mind that the ease with which the fine lead oxide dust can be dispersed into the air will increase the health hazard far out of proportion to the increase in lead content.

Fluxes

ONE of the less known factors in the hazards of soldering is the part played by the flux. The purpose of a flux is to remove the oxide or other film from the parts being joined and allow the molten solder to wet the surfaces completely. Muriatic acid, ammonium chloride (sal ammoniac), and other chloride salts are among the most common fluxes. Since lead chloride is much more volatile than lead or lead oxide, chloride-containing fluxes tend to increase the lead hazard.

Fig. 2 shows the increase in vapor pressure of lead and lead chloride with increased temperature. At about 950°F the vapor pressure of lead amounts to 1.5 milligrams per 10 cubic meters (the generally accepted limit for air-borne lead). This is above the ordinary range of soldering temperatures and is near the melting point of lead chloride. The corresponding vapor pressure of lead chloride at 950° F amounts to about 50,000 milligrams of lead per 10 cubic meters. This shows that while lead itself as a vapor or fume is not significant in the range of soldering temperatures (but may be in cases of local overheating such as in flame soldering), the vapor of lead chloride may be highly important. Dust is, of course, the main source of air contamination at all temperatures, but, at higher temperatures, oxidation to a fine dust is more rapid.

Rosin is the common flux used in soldering electrical equipment where chlorides must be avoided. Many exhaust systems have been put in primarily to control the irritating smoke arising from rosin flux.

When a flux is chosen the desired properties from a technical standpoint are: effecting a good bond between the parts, increasing production, and not favoring corrosion. From the health standpoint, the only common consideration in the choice of a flux has been a "guarantee" that it will not irritate the nose, throat or skin. However, the important properties of a flux from the standpoint of the lead hazard are (1) absence of chlorides, and (2) tendency not to produce a dry, powdery film of lead oxide.

To label a flux as "harmless" merely because it is non-irritating is misleading because this quality is no measure of the lead hazard.

Fluorides are among the most hazardous of the common flux constituents. They are rarely used in lead soldering but commonly in silver soldering.

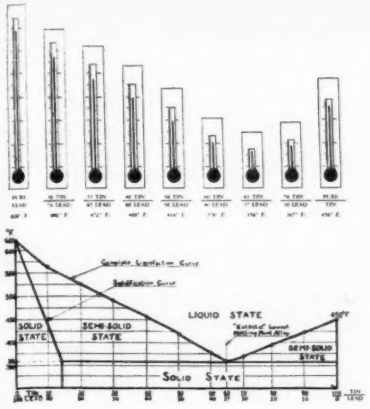


Fig. 1.

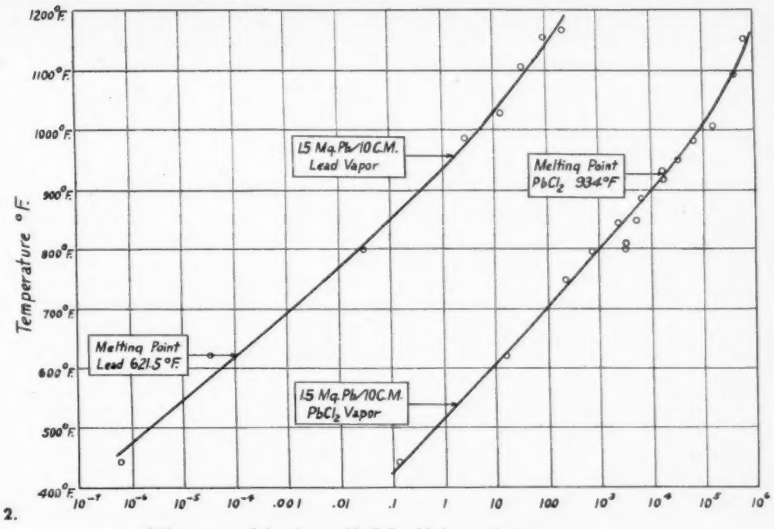


Fig. 2.

Solvents

SOLVENTS also affect the hazards of soldering operations. Carbon tetrachloride, xylol, alcohol and other solvents are sometimes used when a flux is to be applied in solution. War contracts usually specify the removal of flux residues by means of solvents. Some of the solvents used in this way have been mixtures of methanol and benzol. It is common to substitute non-flammable solvents to eliminate the fire hazard and at the same time not consider the increased health hazard. In one plant, because of a fire, the flammable solvent was replaced by trichlorethylene with no control of the vapors. Carbon tetrachloride, which is often specified for cleaning soldered joints, is one of the most dangerous non-flammable solvents. Complaints of nausea have been made where these chlorinated solvents have been used without control of the vapors. Fig. 14 shows how one plant is controlling the vapors from a solvent cleaning operation by local exhaust.

The Lead Hazard

THE chief point of attack in preventing harm from soldering operations is control of lead dust. Although adequate personal hygiene facilities and acquainting the workers with the hazards will go far toward preventing lead poisoning by ingestion, that is only part of the picture. The most important mode of entry of lead is by breathing, and the principal job of the industrial hygienist is to keep the lead out of the workroom air.

The first step in evaluating the hazard at soldering operations is to determine the lead concentration in the air. Fortunately, we have in this case a well established limit, and the degree of control is determined by the extent to which the lead concentration is kept below 1.5 milligrams per 10 cubic meters; that is, how large a factor of safety is being maintained. The results of this investigation show that it is no great engineering feat to achieve and maintain lead concentrations well below this limit.

In our survey we have determined the lead concentration in the air at 160 operations involving soldering in 84 plants, and from this survey we have learned what is necessary for adequate control. The majority of the samples were taken in selected environments where there was some question of the hazard. Some were taken to determine the effectiveness of different control methods, and others to find out how much the lead concentration could be reduced and how it could be kept at that low level.

In many environments it is not necessary to take air samples in order to decide that one or more conditions are not satisfactory. On the other hand, to be reasonably certain that control measures are being consistenly maintained, it is necessary to determine the lead content of the air throughout the cycle of operation after good control has been established. Harmful quantities of lead, which would not be suspected from visual observation, may be present in the air but would be revealed only by air samples.

Hand Soldering—Soft Solders

ON THE basis of the hazards and methods for their control, hand soldering operations may be divided into four types: gas-heated irons, electric irons, tinning, and torch soldering. Table II gives a summary of lead findings on air samples taken at soldering operations. Note the third vertical column in Table II, which lists the number of samples found under 0.3 milligram, that is, those having a factor of safety of five or more.

It should be emphasized that, in addition to the lead hazard, other hazards may be presented by hand soldering operations. For instance, when impregnated coils or condensers are soldered or tinned, poisoning and severe

TABLE II.

AIR CONTAMINATION BY LEAD-SOLDERING OPERATIONS
157 AIR SAMPLES FROM 82 PLANTS

TYPE OF OPERATIONS	NUMBER OF SAMPLES	MILLIGRAMS OF LEAD PER 10 CUBIC METERS OF AIR					
		UNDER 0.3	0.3 TO 0.7	0.7 TO 1.5	1.5 TO 2.5	2.5 TO 4	OVER 4
GAS HEATED IRONS	37	6	4	8	9	6	4
ELECTRIC IRONS	32	9	8	6	6	3	0
TORCH SOLDERING	21	9	4	1	2	1	4
TINNING LARGE SMALL POTS	39	8	11	5	6	3	6
MACHINE SOLDERING	28	1	3	5	3	5	11
TOTALS	157	33	30	25	26	18	25
		UNDER 1.5 88			OVER 1.5 69		

dermatitis may be caused by the volatilized chlorinated waxes.

GAS IRONS: In the oldest type of soldering the irons are heated by some fuel, usually gas. This method is still commonly used for heavy work, such as soldering of radiators, sheet metal ducts and ammunition cases. The muffle furnace used in heating the iron is usually the principal source of air contamination by lead. The flame, by playing on bits of solder which fall to the muffle floor, burns or vaporizes these droppings and blows the finely divided lead oxide into the surrounding air. Gordon C. Harrold[1] has shown how serious this condition can be, and that it is essential to provide a complete enclosure of the muffle and mechanical exhaust. These lead deposits in the muffle are often major sources of contamination even when soldering is not continuous. Removing this dross by any but vacuum methods is likely to cause enormous air contamination.

We have found the highest proportion of high lead concentrations where gas-heated irons are employed. This is due to the relatively large amounts of solder used, frequent overheating, use of chloride flux, and use of muffle furnaces. The 37 samples at operations with gas-heated irons showed lead concentrations from 0.09 to 4.79 milligrams, with a number near the limit of 1.5.

An example of good control of gas-heated irons is illustrated by a sample taken where six operators were soldering ammunition cases. This sample showed 0.2 milligrams of lead per 10 cubic meters of air. Very good exhaust was furnished through a six-inch slot at the back of the bench, providing 600 linear feet per minute into the opening. The muffles were located near the exhaust hood and an air velocity of 75 linear feet per minute was maintained at the far edge of the bench. Housekeeping was good, largely because the exhaust effectively carried away the fine dust thrown out by the muffle or scraped off the iron itself.

An example of poor control was found at another location of similar heavy soldering, where one operator was soldering automobile heaters, and the lead concentration in the air was 3.22 milligrams. The operation was hooded but the mechanical exhaust was inadequate and housekeeping was poor.

ELECTRIC IRONS: Electric irons are used in great numbers in the radio and electrical industries and other industries where much light soldering is done. These operations are often exhausted primarily to eliminate the fume arising from the flux, but fortunately these controls have also reduced the lead exposure. Where large numbers of irons are used in the same area and where housekeeping is not good, the lead concentration is likely to be excessive.

In order to reduce this exposure some plants have provided a chimney or stack above the soldering operations, extending about two feet into the air. The idea is to draw part of the contaminant away from the operator and discharge it into the workroom where it would be diluted with the general air. Six of the 32 samples were taken at operations with such an arrangement. They indicate that the use of the chimney has no effect on the lead exposure.

Another makeshift practice is to provide a small fan which blows the air across the work and away from the operator. Three of the "electric iron" air samples were taken where fans were used in this way. All three were above the limit. A fan used in this way is definitely bad, since it increases the lead exposure by stirring up any fine dust. Cooling fans may be desirable, but the air current should be shielded so as not to blow across the operation or past the opening of an exhaust hood.

The 32 samples taken at electric iron soldering operations ranged from 0.14 to 3.69 milligrams of lead per 10 cubic meters of air with the majority near the lower side. Two of these examples are selected to illustrate good and poor control.

An air sample taken at an operation having exhaust similar to that shown in Fig. 7 and very good housekeeping, showed 0.14 milligrams of lead per 10 cubic meters of air. Thirty-five people were working in the area, soldering condenser plates with 100-watt irons. A sample taken immediately afterward with the exhaust off showed 0.34 milligrams. This substantial increase can be attributed only to the turning off of the exhaust. The effect of the housekeeping would be shown at a later time because the fine dust, which had previously been removed by the exhaust, would now accumulate and add to the exposure. In other words, exhaust aids in good housekeeping.

Another air sample, where two men were using 150-watt irons in soldering armatures, showed 3.38 milligrams of lead per 10 cubic meters of air. The irons were clean but there was some powdery dross on the bench.

An attempt at exhaust by means of a high canopy was quite ineffective.

CLEANING SOLDERING IRONS: After continued use, irons become coated with a layer of metallic oxides and this coating must be removed periodically to furnish a clean surface of copper for tinning. Cleaning of irons may disperse more lead into the air than the soldering operations themselves. Whether each solderer cleans his own iron or the job is done in one location by a man assigned to that job, the filings or dust must be controlled. At a filing operation we found 0.4 milligrams of lead per 10 cubic meters of air; the necessary control here is the trapping and the disposal of the filings in such a way that they will not be ground under foot and dispersed into the air as a dust. At an uncontrolled scratch brushing, grinding and tinning operation on solder irons we found 17.3 milligrams of lead per 10 cubic meters of air. Enclosure and adequate local exhaust were ordered for the control of this serious exposure.

TINNING: In tinning or dipping operations, the hazard arises largely from lead oxide which forms on the metal surface or edges of the pots. This may be carried into the air by the work or dispersed by improper handling of the dross. The larger operations are more hazardous and more difficult to control, but we have found examples of good and poor control in both types.

For example, in one plant, milking machine parts were being dipped in a large pot enclosed in a booth; the actual tinning surface was one foot by two feet. The air velocity into the face opening was 100 linear feet per minute. Since waxy fluxes tend to prevent the formation of powdery dross, the use of this type of flux probably accounts for the very small amount of powdery dross at this operation. An air sample showed 0.11 milligram of lead per 10 cubic meters of air.

In another plant, two three-inch electrically heated pots were used for tinning wire tips. There was powdery dross on the surface and skimmings wre dumped on the table top. An air sample showed 3.95 milligrams of lead per 10 cubic meters of air.

Thirty-nine samples taken at tinning operations ranged from 0.05 to 11.75 milligrams of lead per 10 cubic meters of air. About half of these were at pots or baths five inches or more in one dimension. Note, in Table II, that both large and small operations are distributed throughout the range.

TORCH SOLDERING: In torch or flame soldering, the degree of hazard depends on the size and temperature of the flame, the position of the flame relative to the solder, and, of course, the housekeeping.

One of our samples was taken where the medium size acetylene flame used for solder-sweating of fairly large ordnance parts played on the solder surface about half of the time. The exhaust provided an air velocity of about 200 linear feet per minute past the flame and 1000 linear feet per minute into the duct about four inches away. There was no visible dross and the air sample showed 0.05 milligram of lead per 10 cubic meters of air.

Another sample was taken where copper floats were being soldered and no exhaust was provided. The work traveled past a fixed gas flame of moderate size. The flame played on the soldered surface much of the time. Housekeeping was only fair and, although there was no visible powdery dross in the immediate vicinity, an air sample showed 4.93 milligrams of lead per 10 cubic meters. This is evidently due to the flame playing directly on the solder surface as in lead burning.

Twenty-one torch soldering samples varied between 0.05 and 12 milligrams, with the majority near the two extremes. The reason for this spread is that most of the samples were taken in one plant with very great variation in the housekeeping.

"Silver Soldering"—Hard Solders

"SILVER SOLDERING" operations are being used increasingly in modern industry. Lead is not a factor in these operations but other hazards, at least as great, are presented. The principal hazards are the fluorides present in most of the fluxes and the cadmium which is generally present and may constitute as much as 20% of the solder. Fluorides are most likely responsible for the complaints of nasal irritation, and our observation of scabs on the nasal septum. Since both fluorides and cadmium are among the most dangerous industrial poisons, safe practice requires that "silver soldering" operations be provided with adequate local exhaust. The methods later illustrated for control of lead soldering operations are applicable to silver soldering operations as well.

TABLE III.
CADMIUM IN AIR SAMPLES

Operation	Mg. Cd per 10 c.m.	% Cd in Solder	Enclosure	Exhaust	Housekeeping
Sweating-furnace.....	0.035	11	Fair	Poor	Fair
Sweating-furnace.....	0.059	11	Fair	Poor	Fair
Sweating-furnace.....	0.130	11	Fair	Poor	Fair
Sweating-furnace.....	0.182	11	Fair	Poor	Fair
Torch soldering.....	0.332	11	None	None	Poor
Torch soldering.....	0.568	11	None	None	Poor

Table III shows the findings on cadmium in a few air samples taken at two types of "silver soldering" operations. In all these cases the cadmium is below the limit of 1.0 milligram per 10 cubic meters of air. Note that it is not much below this limit at the flame soldering operations. In all six of these operations, we are dealing with a combined hazard and the fluorides, which were immediately detectable by irritation of the nose, are also an important factor in the toxicity of the "fume." These partial data are presented to indicate that cadmium can be at least a potential hazard and that both cadmium and fluorides must be considered in "silver soldering" exposures.

Effect of Housekeeping and Exhaust

GOOD housekeeping and properly designed local exhaust are the most important measures for controlling the lead hazard at soldering operations. Table IV shows the results of a number of air samples taken in one plant.

TABLE IV.
INFLUENCE OF HOUSEKEEPING ON AIR-BORNE LEAD IN ONE PLANT

Survey Number	Agency	Number of Air Samples	Average Milligrams of Lead per 10 Cubic Meters of Air	Housekeeping
1	I	1	12.0	Poor
2	P	2	0.4	?
3	I	3	5.2	Poor
4	Both	6	0.1	Very good

Light metal articles were being joined by torch soldering. The flame was small and actually played on the solder only a minor part of the time. No enclosure or exhaust was provided for the operation. During Survey 1 an air sample taken by the Industrial Hygiene Division of the Illinois Department of Labor showed 12 milligrams of lead per 10 cubic meters of air. Housekeeping was poor, and an order was issued for improvement in housekeeping and provision of an enclosure and local exhaust.

In the meantime, a private agency had taken two air samples at this operation and found the lead concentration in the air to be low. This Division then collected three additional samples and again found high concentrations of lead. At the time of Survey 3 the housekeeping was poor. In view of the discrepancies, the two agencies visited the plant together and collected three pairs of simultaneous air samples. At the time of Survey 4, the housekeeping was very good and all the findings were quite low.

This illustrates the importance of good housekeeping and also the practical difficulty of consistently maintaining good housekeeping unless local exhaust is provided. It also shows how much the air contamination can vary due

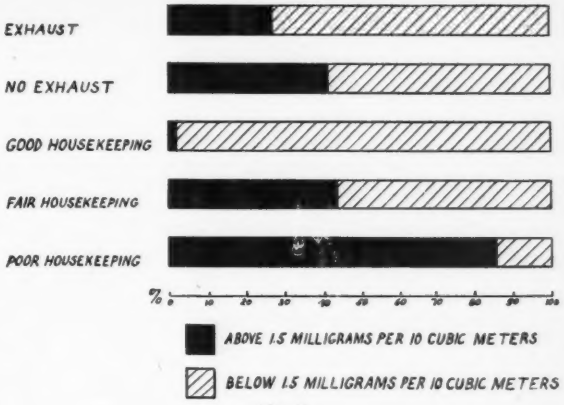


Fig. 3.

to apparently minor causes. Starting with a clean workbench but no exhaust, the air contamination may at first be relatively low. It is likely to increase sharply as small amounts of powdery oxides accumulate and are re-dispersed by air currents. With a good exhaust system and reasonable care in housekeeping a high factor of safety in air contamination will not only be achieved but will also be maintained indefinitely.

Good housekeeping, with reference to a lead hazard, applies particularly to the powdery dross which may get into the air as fine, usually invisible, dust. Vacuum cleaning of floors and benches is important, and it is practically impossible to maintain good housekeeping throughout the work day unless good exhaust is provided.

The bar graphs (Figs. 3 and 4) are based on the 129 air samples taken at hand soldering operations. In the first two bars of Fig. 3 all the samples are divided only on the basis of exhaust or its absence. The proportion above 1.5 milligrams is much greater when no exhaust is used. "No exhaust" includes operations where the exhaust was quite ineffective. Each bar represents all the samples in the particular category and the solid part represents the proportion which are above 1.5 milligrams.

In the last three bars (Fig. 3) all the samples are classified on the basis of housekeeping. When good housekeeping is maintained, the air contamination is nearly always under 1.5, whereas with poor housekeeping it is almost as likely to be above that limit.

For Fig. 4 the 129 air samples were divided into six groups based on three variations in housekeeping combined with the presence or absence of exhaust. The top three bars include all the samples having exhaust and the bottom three those without exhaust. The influence of housekeeping is again shown by the progressive amount of black on each group of three bars. The bars may also be considered in pairs having the same kind of housekeeping—the first and fourth good, the second and fifth fair, and the third and last poor housekeeping. The most significant bar is the top one representing the samples with good housekeeping and exhaust. These represent all types of hand soldering. Note that none is above 1.5 milligrams. In fact, they range from 0.05 milligram to 0.61 milligram,

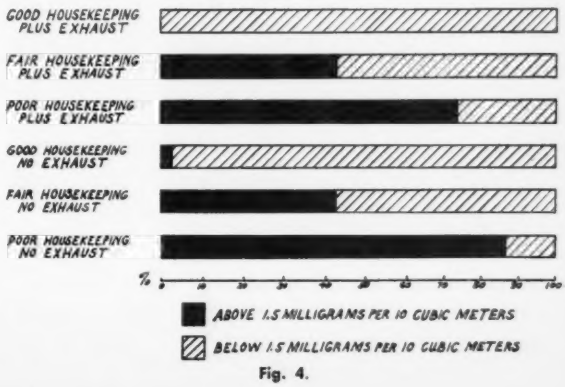
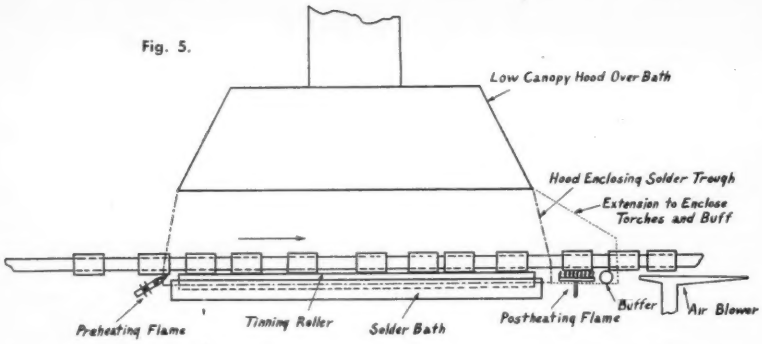

GOOD HOUSEKEEPING PLUS EXHAUST
FAIR HOUSEKEEPING PLUS EXHAUST
POOR HOUSEKEEPING PLUS EXHAUST
GOOD HOUSEKEEPING NO EXHAUST
FAIR HOUSEKEEPING NO EXHAUST
POOR HOUSEKEEPING NO EXHAUST
%
ABOVE 1.5 MILLIGRAMS PER 10 CUBIC METERS
BELOW 1.5 MILLIGRAMS PER 10 CUBIC METERS
Fig. 4.

Fig. 5.



the highest showing a factor of safety of nearly three, and the average being 0.24 milligram.

Of the 29 hand soldering samples taken at operations with exhaust, 13 had good housekeeping and six poor housekeeping. Of the 100 hand soldering samples taken at unexhausted operations, 38 had good housekeeping and 29 poor housekeeping. These figures show a definitely higher frequency of good housekeeping where exhaust is used, but this is not very pronounced (45% good housekeeping with exhaust and 38% good housekeeping without exhaust). It should be borne in mind that this is a selective group of samples and general observations point to a much greater improvement in housekeeping due to exhaust than this would indicate. On the other hand, there has at times been an apparent tendency to regard an exhaust system as a cure-all with consequent laxity in housekeeping.

Machine Soldering

MACHINE soldering is used where a large number of soldered parts are needed. The manufacture of floats and the fabrication of certain ordnance parts are special adaptations, but the can industry continues to be by far the most important application. From the industrial hygiene standpoint, machine soldering differs from hand soldering in that there is:

1. A larger surface of molten metal exposed to oxidation.
2. Continuous agitation of the surface.
3. A larger and more continuous volume of work.
4. The use of a gas torch or torches to preheat the work or to post-heat the soldered seam.

The can body seam machine, or body builder, is the most important soldering machine (Fig. 5). Strips of tin plate of the proper size are stacked in a pile at the entering end. These are removed one at a time from the bottom of the pile, bent into a cylinder and the seam formed and rolled flat by interlocking the edges. Flux is applied to the seam by a wiper and the seam may be preheated. The can body is then carried over a long solder bath and a metal roll the length of this bath wipes the outer part of the seam with solder. Beyond the bath there may be a post-heating gas torch or torches which play on the soldered surface as it passes rapidly along. This surface is wiped by a rotary cloth buff, and the partially fabricated cans pass over a blast of air for cooling the solder before they are dropped into the conveyor to the next operation.

The post-heating torch and the wipe after the cans leave the bath are important sources of toxic lead dust, and the exhaust hood, to be effective, must enclose both. If the cooling air blast is too near the wiper it will interfere with the exhaust. Some samples were taken at a location with rather low, exhausted canopies which usually covered only the solder bath. Other samples were taken where the sides and ends of the canopies had been dropped to form an enclosing hood. In too many cases the post-heating torch and buffer were not enclosed.

Most of the body builders are similar to the above description, but there are special modifications for oblong cans, on some of which the handle and spout are soldered to the body. The ends are ordinarily rolled into place with a thin rubber gasket, but in the case of milk cans the ends are soldered on. Ths is done on a machine called a floater, with a long lead bath similar to that on the body builder. Control of the lead hazard at the floater is similar to that at the body builder, but added control is necessary where the rough solder is buffed off the ends. Most of this knocked-off solder is, of course, in the form of heavy metallic granules, but the rapidly revolving brushes also disperse a large amount of very fine metallic dust. While an attempt is usually made to enclose these buffers, as a rule either no exhaust or inadequate exhaust is provided. The accumulation of solder granules must be removed and handled with great care to prevent dispersion of fine metallic dust. The Wisconsin State Board of Health reported a thorough study of the lead hazards in the milk can industry about a year ago.[2] In general, our findings, as represented by Plant B in Table V, agree with those reported in the above study.

The flux used for soldering cans gives rise to much visible smoke which is irritating, and that is why in the older system of exhaust the hood was designed to cover only the bath. The seam flux is a solution of rosin in alcohol and a layer of chlorides is used as a flux on the bath. Now it is fairly well recognized that the torch used in post-heating is an important source of air-borne lead and that good housekeeping is most essential. The high lead, tin conserving solders have greatly increased the hazard.

Air Samples at Machine Soldering Operations

THE machine soldering samples listed in Table II were all taken in the tin can industry. These 28 samples showed air contamination ranging from 0.19 to 48.5 milligrams of lead per 10 cubic meters of air. The general range of the samples is high. Five of the 11 highest showed air contamination by lead higher than any taken at hand soldering operations.

TABLE V.
CAN BODY SEAM MACHINES

Sample	Plant	Mg. Pb. 10 C.M.	Percentage Lead	Enclosure	Exhaust	Housekeeping
1	A	0.34	30	Poor	Fair	Good
2	A	1.43	50	Poor	Fair	Fair
3	A	2.13	70	Poor	Fair	Fair
4	A	23.8	98	Poor	Fair	Fair
5	A	1.54	70	Fair	Fair	Fair
6	A	4.96	98	Fair	Fair	Fair
7	B	2.36	30	None	None	Fair
8	B	7.37	30	Good	Good	Very Poor
9	C	18.8	30	Poor	Poor	Very Poor

Table V shows the results of nine of these air samples taken at breathing zone level at body builders (seam machines), usually about three feet out from the exit end. These results illustrate the importance of housekeeping, enclosure and exhaust, and the significance of the percentage of lead in the solder. The percentage of lead is closely related to the melting point, and hence the amount of oxidation and powdery lead oxide formed.

The first four samples show a series of increasing lead content with control factors about the same. The first sample was taken several years earlier when 70% tin solders were commonly used. A moderately low canopy was provided over the solder bath, and there was enough exhaust to remove nearly all the visible smoke from the flux. Under favorable conditions this gave rather good control of the low lead solders. The second sample was taken later when there was a higher percentage of lead in the solder, which required only a slightly higher working temperature. The increased amount of lead in the air is not great considering that the housekeeping was only fair. Samples 3, 4, 5 and 6 were taken the same day. Nos. 3 and 4 show how ineffective the old type of control is with the higher lead content solders. Where samples 5 and 6 were taken, enclosure on the machines had been improving by dropping the sides of the canopy to form

a hood over the solder bath. This was only partially effective because it did not enclose the post-heating torches. Additional post-heating torches are required with the higher lead solders and these added flames playing directly on the solder surface are a very bad source of contamination, especially when drops of solder fall and oxidize on the burners.

TABLE VI.
CAN BODY SEAM MACHINES

Sample	Plant	Mg. Pb. 10 C.M.	Percentage Lead	Enclosure	Exhaust	Housekeeping
1	D	0.47	70	Fair	Good	Good
2	D	0.91	70	Poor	Good	Good
3	D	0.19	98	Good	Good	Good
4	D	0.75	98	Good	Good	Good
5	F	4.55	75	Poor	Fair	Poor
6	F	5.76	70	Poor	Fair	Poor
7	E	13.5	70	Poor	Poor	Very Poor
8	E	15.1	70	Poor	Poor	Very Poor
9	E	48.5	70	Poor	Poor	Very Poor

The other three samples show how bad conditions could be when poor control was applied even to the low lead pre-war solders. Samples 7 and 8 are especially interesting. When sample 7 was taken there was no exhaust and an order was issued for such control. On returning, when a good system had been completed and in operation for some time, it was found that the housekeeping had deteriorated and, as a result, the air contamination was worse than before.

Good control is better illustrated in Table VI. Sample 1 was taken at a machine with an enclosing hood over the bath but the torch was not enclosed. The amount of air exhausted was so great that any lead dispersed by the torch was fairly well controlled. Sample 2 was taken at a similar machine with a low canopy and the same large amount of exhaust. It was pointed out to the management that sample 2 was only slightly below the limit while sample 1 showed a factor of safety of three. On the basis of this evidence the management was convinced of the advisability of providing better enclosure of the torches on all machines.

Samples 3 and 4 were taken a few months later when these improvements had been instituted and the higher lead solder was in use. The two machines and the control measures were quite similar, with the hood extending over the torch, and sufficient exhaust to give a minimum of 200 linear feet per minute into all openings. Terne plate, not tin plate, was used in the machine where sample 4 was taken. The housekeeping was only fairly good in any of the four cases. Since that time vacuum cleaning of the floors has been instituted, and powdery drosses are being handled with greater care so that the exhaust system can effectively pick up any unavoidable spilling. With these improvements a low concentration of lead in the air, of the same order as sample 3, will be easy to maintain.

Samples 5 and 6 were taken at a plant using slot exhaust along the solder bath. There was a noticeable amount of powdery dross on the floor. The exhaust had little effect on the lead dispersed from the post-heating torch because the exhaust slot was set about a foot away from the torch. Although control by slot exhaust requires less air than a hood, in order to be effective the slot must be brought sufficiently close to all sources of contamination. However, cross currents of air in the room are more likely to interfere with a slot type of exhaust system than with the type using complete hood enclosures. Exhaust slots which may have given adequate control when lower lead solders were used may be totally inadequate when shifting to the high lead solders which tend to form more powdery dross.

Samples 7, 8 and 9, which show some of the highest lead concentrations in this series, were taken about three feet out from the entering, middle and exit ends respectively of the same machine. Although a low canopy hood removed most of the flux smoke, it was provided with so little exhaust that the air velocity could not be measured at the top edge of the bath where the powdery drosses tend to collect. The considerable amount of powdery dross which was spilled on the floor and tracked about was an important factor in the high lead concentrations found in these air samples.

Control Measures

FIG. 6 illustrates a type of hand soldering booth for controlling the lead hazard by a system of local exhaust which facilitates the maintenance of scrupulous housekeeping. This design embodies the features of installations observed in the field and may be adapted to most types of hand soldering operations. Where gas-heated irons are used it is essential that the muffle be located within the hood. Unless irons are cleaned inside this booth the cleaning operation must be provided with its own enclosure and exhaust. A metal pan set under a removable grille at the front of the booth catches the dross and drippings. When these accumulations are removed, the receptacle must be placed in the booth and the exhaust must be operating.

The air volume is based on 100 x HL cubic feet per minute. The velocity in the pipes should not exceed 2000 linear feet per minute for economy of operation. If L is over five feet the booth should be provided with two branch pipes. The type of control illustrated here is especially adaptable to moderately large parts such as milk cans, ammunition cases, etc., or for torch soldering. For many operations a quite different design may be more practical. The following photographs show the set-ups which have been proved effective in controlling the lead hazard at different types of soldering operations.

Fig. 7 shows the use of an electric iron with the exhaust hood quite close to the work. Visible smoke from the flux does not get into the breathing zone and the housekeeping is good. The speckled appearance of the bench top is due to the pattern in the linoleum. The air velocity was 3000 linear feet per minute into the four-inch duct. The velocity falls off very rapidly with increasing distance between the working position and the exhaust hood; in this case, six to eight inches away from the hood, where the work was being done, the velocity had dropped to 150-300 linear

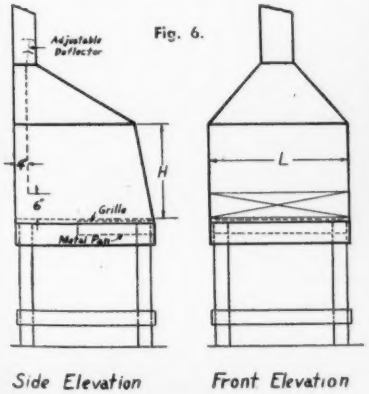


Fig. 6.

Fig. 7.
Hand soldering, electric iron, exhaust hood fairly near operation

Fig. 8.
Same operation as Fig. 7; note fume being drawn toward hood and main duct

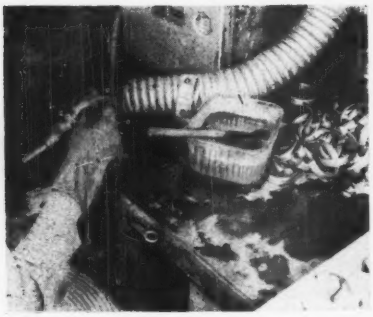


Fig. 9.
Electric resistance soldering, exhaust duct close to work

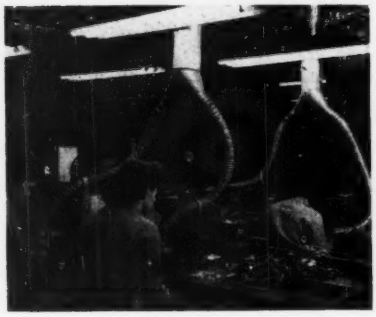


Fig. 10.
Exhaust ducts brought to several operations like one in Fig. 9

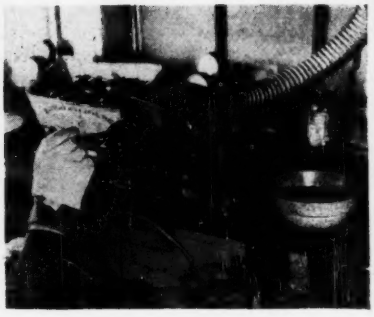


Fig. 11.
Torch soldering, movable exhaust hood

Fig. 12.
Electric soldering, gauges mounted in jig, slot exhaust

Fig. 13.
Torch soldering, fixed torches, parts on turntable, low canopy

Fig. 14.
Fixed electric iron, lamp shade serving both as light reflector and exhaust hood

Fig. 15.
Exhaust booth for control of vapors in solvent cleaning of excess flux

Fig. 16.
Adjustable exhaust hood for tinning pot

Fig. 17.
Use of fixture and adjustable exhaust hood is more difficult type of control

feet per minute. An air sample taken at the breathing zone of the operator indicated 0.28 milligram of lead per 10 cubic meters of air.

All photographs reproduced in this paper were taken in war plants, but the fact that the work may be considered "temporary" has not prevented the managements from installing good control. Fig. 8 shows more of the duct work at the same location pictured in Fig. 7. The small hood on the end of the branch duct assists in directing the flow of air and helps to obtain an effective velocity of 150 linear feet per minute or more past the main point of origin of the lead dust.

Fig. 9 is a close-up of an electrical resistance soldering operation. In this case the 2½ inch duct can be brought very close to the operation and no expansion of the end is needed. Note the use of a rubber glove to prevent skin injury from the flux. The housekeeping is only fair, as shown by the dry spots and small quantities of visible dust. The sloppiness due to poor handling of the flux is not significant in the lead exposure. An air sample taken here, (same operation as performed by girl at the right in the back row Fig. 10) showed 0.19 milligram of lead per 10 cubic meters of air. The air samples taken at locations shown in these photographs were not included in the tables or bar graphs.

Fig. 10 is the same location as Fig. 9 showing the duct work reaching to several operations. By using flexible branch pipes it is possible to adjust the position of the opening for maximum efficiency in collecting the fumes. With so small a duct, it is very important that the opening be kept within effective range of the work.

Fig. 11 shows a torch soldering operation with the small fixed hood near the work which was clamped in a vise. Housekeeping was only fair but the waxy flux helped to keep the dust to a minimum. The air velocity was 700 linear feet per minute at the face of the hood and about 100 past the work. The high temperature of the flame accelerates the production of powdery oxides and unless this dust is carried away by exhaust it settles and becomes a source of recontamination. An air sample taken here showed 0.08 milligram of lead per 10 cubic meters of air.

In Fig. 12 an electric iron is being used with an exhaust slot at the back of the table. The housekeeping was good and was aided by the exhaust. The air velocity was 800 linear feet per minute at the slot and 200 at the work. The velocity in this type of exhaust is effective farther away because of the larger volume of air through the long slot and because the table top serves as a partial enclosure.

Fig. 13 shows a small flame soldering operation with the flame fixed and the work traveling on a conveyor. Housekeeping was good but not excellent. The sign warns against eating at the work place. Air velocity at the top edge of the canopy was 200 linear feet per minute and 150 at the work. Although in this type of exhaust hood the velocity falls off less rapidly than with the types previously illustrated, if the canopy were a little higher it would cease to be effective.

Fig. 14 shows a lamp shade used as a hood attached to a 2½ inch duct. The light inside the shade aids visibility. This is a good type of control for an iron in a fixed position. The air velocity was 1500 at the face of the opening and 250 to 300 linear feet per minute at the work.

Fig. 15 illustrates the use of a small hood for removing vapors in solvent cleaning of excess flux on soldered coils. The parts are allowed to dry in the enclosure and since the face opening is quite small an effective velocity can be maintained with a relatively small volume of air. The small opening is made feasible by a plastic window through which the operation can be observed.

Fig. 16 shows the use of a moderately large exhaust slot extending close to the edge of a small electrically heated tinning pot. This hood can be rotated in an arc or adjusted up or down. Note the wooden box into which the pot has been placed in order to faciilitate housekeeping.

Fig. 17 illustrates the use of an adjustable system of slot exhaust at a soldering assembly operation. With modifications in the work the flexible section permits lowering or raising and the duct swings in a four-foot radius. Note the holder for the iron on the edge of the bench. This holder catches dross falling from the iron when it is not in use, and promotes good housekeeping.

While this by no means includes all the possible methods of ventilating control of soldering operations, the illustrations have shown practical methods which can be adapted to most types of work. No matter which system is chosen, it must incorporate or be accompanied by scrupulous housekeeping—the trapping and disposal of dross.

Summary

IN ALL types of lead soldering, dangerous quantities of lead may be dispersed into the workroom air.

2. The principal sources of air-borne lead are locations where powdery drosses are formed, and these require careful control. Of greatest significance are: gas muffle furnaces, surfaces and edges of solder pots and baths, flames playing on a solder surface, any location where solder may spill and be burned to a powdery oxide, and the irons themselves.

3. High-lead solders multiply the hazard because of the more rapid oxidation of the lead at the higher working temperature.

4. Good housekeeping is essential. Cleaning must be done only by vacuum methods. What would be considered good housekeeping at most operations may be poor or fair when applied to soldering operations.

5. Air samples indicate that the only dependable type of control is a combination of scrupulous housekeeping and properly designed local exhaust. Several practical methods are illustrated.

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Quinacrine Dihydrochloride

—Occupational Disorders and Their Control—

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QUINACRINE dihydrochloride (atabrine) is a synthetic yellow dye of the acridine series, and has come into prominence lately only because of its extensive use as a substitute for quinine in the prophylaxis and treatment of malaria among our armed forces. Its irritating effects upon workmen who handle it in the manufacture of tablets would be of very limited interest under any other circumstances, but are described in this paper partly because they have never appeared in medical literature before and partly to illustrate how this particular industrial hazard was controlled by specially-designed machinery.

The Manufacturing Process

THE chemical synthesis of quinacrine involves a number of stages, and in some of these, toxic or irritating intermediate compounds must be handled. At Abbott Laboratories we were concerned only with the final step, in which halocrine is coupled with novol diamine in molten phenol. Following this, a series of recrystallizations is carried out to produce the purified quinacrine. These steps are illustrated in the accompanying flow-sheet (Fig. 1). An outstanding difficulty of this process is the large number of times the material must be manipulated by hand, but, since it is always in a moist condition until the final step of drying, the most troublesome hazard—a light, fluffy dust—is not encountered.

In making practically all machine-compressed tablets, it is necessary first to prepare the drugs in a

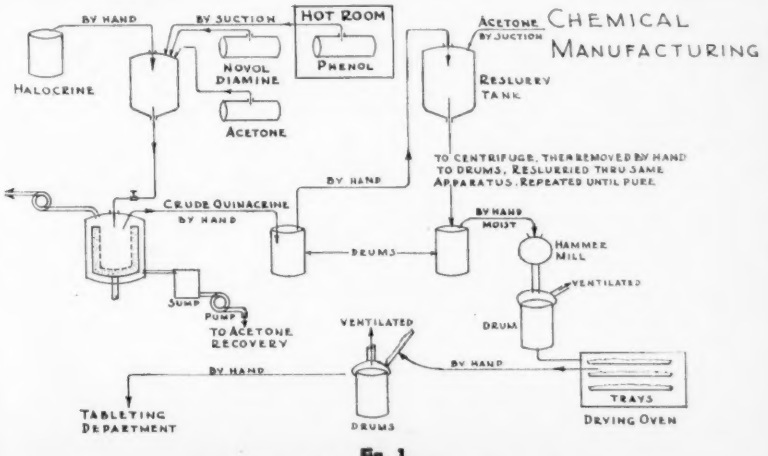


Fig. 1.
Flow sheet of chemical manufacturing operation

Fig. 2.
Full costume of workmen

granular form which will flow freely. This is most frequently done by moistening the mixture with an appropriate solvent, spreading it on trays to dry, and grinding the dried material to a coarse granular consistency. In the case of quinacrine, this procedure cannot be followed; instead, it is necessary to feed the powdered mixture of drug and excipients into a machine which forms it into large discs called "slugs." These are coarsely ground and fed to a second machine of the same type which re-forms the material into slugs. The coarse granulation produced by grinding these secondary slugs is suitable for use in tablet machines.

The ordinary slugging, grinding and tablet-compressing machines used in the pharmaceutical industry are designed to be fed by hand, and the escape of considerable amounts of dust is not ordinarily considered dangerous. It can readily be understood, therefore, that the performing of so many operations on a highly irritating and dusty material such as quinacrine would give rise to much illness unless special engineering precautions were adopted. An elaborate exhaust system was designed by the engineering department of Abbott Laboratories, and by its use the dust exposure was reduced to very low levels, as shown in Table I.

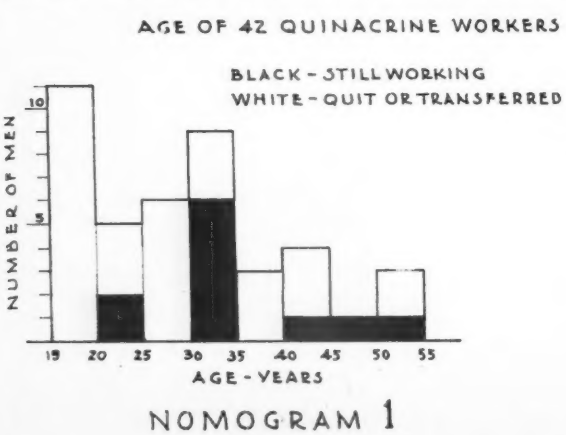
TABLE I.
QUINACRINE CONTENT OF TABLET-ROOM AIR*

Sampling Point and Conditions	Micrograms per Liter
Floor level. All machines operating. Dryers being emptied in adjacent room	0.35
Platform beside rotary mixer during filling	4.2
Platform of slugger No. 1. Operator's station	2.1
Floor level. All machines operating. Contents of portable hopper dropped in tablet machine	1.8
Same as previous sample	1.8

*Though many more accurate and refined methods of determining quinacrine have been developed, the following rough method was found adequate for the air analyses:

Air was passed through 10 cc. of distilled water in a midget impinger of the M.S.A. type. One cubic foot of air usually contained enough quinacrine to impart a faint yellow color to the water, which was transferred directly to colorimeter tubes and compared with standards made by diluting a standard solution of quinacrine hydrochloride in water. The standard solution contained 100 mg. of the dye in 100 cc. of distilled water. The most useful dilutions were those yielding 2, 4, 6, 8 and 10 micrograms per cc.

The extremely small amounts of quinacrine indicated by the values in Table I can better be appreciated by recalling that the ordinary tablet of this drug contains 100 milligrams, and that daily doses of one or two tablets are commonly prescribed over long periods of time. There is, of course, no question of systemic poisoning from inhalation of dust at these low levels, but the potency of quinacrine as a local irritant is such that even with the elaborate dust-control equipment to be described later in this paper, a wide variety of symptoms was observed in the workmen. These are described in the following section.



NOMOGRAM 1

Occupational Reactions to Quinacrine

DURING a period of eight months, 42 men were exposed to the drug. They were distributed as follows:

	Not now working	Now working	Total
Chemical mfg.	9	6	15
Tablet mfg.	20	7	27
Totals	29	13	42

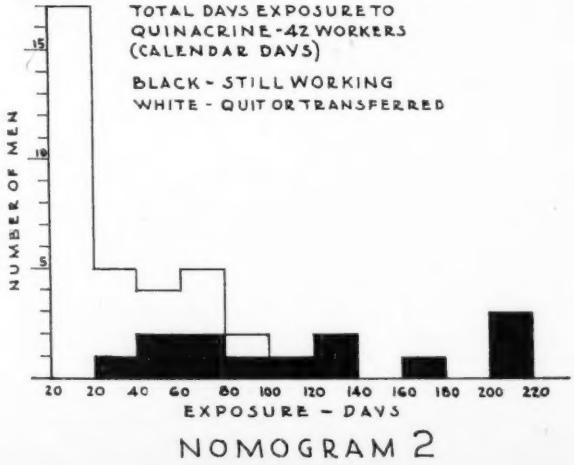
Those not now working were either transferred to other jobs in the factory because of reactions, or resigned because of reactions or because they objected to the work or because they were only temporary employees. The ages of the employees, both working and not working, are shown in nomogram 1. The total exposure of employees of both categories is shown in nomogram 2. These graphs indicate that workers below the age of 20 have poor staying power for this job, that most workers drop out for one reason or another before they have spent 40 days on the drug, and that few workers drop out after spending 100 days.

All reactions caused by quinacrine in our experience had the nature of local irritations, and affected the eyes, nose, skin, and mouth most frequently. Many workers had more than one site of irritation; some were irritated more than once. A certain individual variation in sensitivity was obvious, but except for a few very sensitive men, it was not possible to attribute this any more to a "constitutional" cause than to variations in carefulness and intelligence. Twelve men never complained of any irritation, yet only three of these are still doing this work. Of the nine who dropped out, two were transferred and seven resigned.

TABLE II.
INCIDENCE OF REACTIONS

	No. of cases	Per cent	Mean exposure before onset	Mean duration of symptoms	Mean lost time from work
Conjunctivitis	22	52	17.3 (1-65)	8.5 (1-25)	2.3 (0-6) days
Keratitis	5	12	26.6 (10-60)	13 (4-24)	1.7 (0-4)
Rhinitis	15	36	19.9 (1-80)	5.7 (1-19)	2.8 (0-7)
Epistaxis	3	7	32.3 (14-61)	11 (2-22)	0
Stomatitis	10	24	14.1 (8-31)	8.2 (4-19)	3.1 (0-6)
Pharyngitis	2	5	55.0 (50-60)	3.0 (1-5)	2.5 (0-5)
Tracheitis	3	7	25.6 (9-56)	7.3 (1-11)	2.3 (0-5)
Bronchitis	1	2	20	5	5
Asthma (or dyspnea)	4	10	27.8 (3-80)	11.8 (1-43)	4.0 (1-10)
Dermatitis	15	36	27.8 (1-180)	12.4 (1-75)	1.4 (0-5)

(Exposure and duration: Calendar days. Lost time: working days)
Figures in parentheses are extreme values.


TOTAL DAYS EXPOSURE TO QUINACRINE - 42 WORKERS (CALENDAR DAYS)
BLACK - STILL WORKING
WHITE - QUIT OR TRANSFERRED
NUMBER OF MEN
15
10
5
20 20 40 60 80 100 120 140 160 180 200 220
EXPOSURE - DAYS
NOMOGRAM 2

Conjunctivitis occurred in all degrees; when severe, it was usually accompanied by a superficial keratitis. The most severe case was that of a tablet machine operator who had a broken piece of slug fly into his eye. Despite immediate irrigation, the eye showed deep staining, and subsequently became very painful. Prophylaxis consisted of providing spectacle-type goggles with side-screens for all tablet operators. In some cases, men came to the plant dispensary every day at the end of the shift for irrigation of the eyes with normal saline. They believed this helped them, but there was no objective evidence to prove it. Treatment of established cases consisted of irrigation of the eyes with normal saline, and application of Abbott's holocaine and epinephrine ophthalmic ointment b.i.d. or t.i.d. Cold compresses were prescribed for pain. Severe cases were referred to a single ophthalmologist, so that he might become familiar with their nature. No case ever developed corneal ulceration or permanent opacity. A common source of the quinacrine in the eyes of men in the chemical division were the drops of liquor flying out of centrifuges when the covers were open, as they had to be when the slurry was being run in. It is also suspected that a fine mist of this liquid is present in the neighborhood of the centrifuge at such times. For this reason, it was recommended that men running slurry into centrifuges wear goggles and masks. New workers in the tablet division, and some in the chemical, probably conveyed quinacrine to their eyes in some instances by incautious use of their contaminated hands, but undoubtedly the commonest route for quinacrine in the tablet division was in the form of dust or small flying particles.

Rhinitis began with a sensation of dryness in the nose; mucus blown from the nose was noted to be stained yellow. Gradually there developed a mild soreness in the nose, and mucus was observed to be streaked with blood. Occasionally more marked bleeding occurred. In well-developed cases, the nostrils appeared inflamed and crusted; the nose was seen to be obstructed. These cases were treated by withdrawal from exposure and the occasional use of Abbott's sulfedex (sodium sulfathiazole-desoxyephedrine solution), and recovered in about six days.

Dermatitis appeared more frequently in the chemical division, where manual operations were more frequent, and most commonly attacked the wrists at the sleeve line, the backs of the hands, and the flexor surfaces of the forearms. In the tablet division, the commonest site was the zone of contact between the face and the dust respirator. Rubber gloves did not prevent dermatitis in the chemical division, because in actual practice the drug always gained access to the inside of the glove. Plain cotton gloves, frequently changed, found favor for a time, but they were not uniformly successful. Many experienced men finally preferred to work with bare hands.

Stomatitis and cheilitis occurred frequently in the tablet department, but a few cases were also noted in the chemical division. The following theory of causation has been concurred in by several men affected by this symptom: The workman becomes affected by rhinitis to the point where his nose is too obstructed for free breathing, but is still able to continue working. He begins to breathe through his mouth, and this becomes dry and sore. Objectively, the lips are dry and cracked, and may show a yellow stain. The mucous membranes of the mouth appear normal, but the tongue and gums become so sore that only soft food can be eaten. Pharyngitis without objective signs may accompany this. This condition was treated by prescribing frequent rinses of the mouth with Abbott's metoso (a flavored mouth wash containing metaphen), diluted with three parts of water and used warm.

Four men complained of dyspnea after exposure to quinacrine. Two of these had previously suffered from asthma, and recognized the recurrence of this disease. The two others did not display diagnostic signs of asthma. It was necessary to remove all these men from further contact.

The personal factor of cleanliness and caution is extremely important in determining the incidence of reactions. The only two men with any kind of previous experience in this work were the foremen of the chemical and tablet divisions respectively. Neither of them has suffered any reaction, although at times they worked almost single-handed at all the operations 60 to 70 hours a week. The bulk of the labor supply for this work was recruited from completely unskilled classes, and they had to work and be trained at the same time. Many had never worked in a factory before, and none had ever handled irritating chemicals. These conditions were the result of the labor shortage, and undoubtedly caused many more accidents to occur than would otherwise have been the case. Where personnel could be rigorously selected and given previous training on non-irritating material, and under conditions of the labor market where carefulness and safe habits could be enforced by ordinary discipline, reactions could probably be reduced to a very small figure.

Industrial Hygienic Measures

THE excellent cooperation and advice of the scientific and medical staff of Winthrop Chemical Company, the original makers of quinacrine in this country, enabled us to be adequately forewarned as to the irritating properties of the drug, and afforded us a rare opportunity to plan our equipment so as to avoid needless exposure of the workmen. My particular thanks are due to DR. O. W. BARLOW, whose accurate observations of the symptoms of quinacrine irritation, freely transmitted in a personal communication, have been confirmed in every respect by my own subsequent experience.

Personal Protective Equipment

THE workmen in both the chemical and tablet divisions were furnished with uniforms of the "coverall" type in sufficient quantity to permit a change of uniform daily (Fig. 2). These suits were white, so that the yellow stains would be more forcibly brought to the workman's attention. The cuffs were made to fit snugly by the use of scotch tape, applied fresh daily. As head-covering, many men favored brown paper bags of the right size; over a period of years these have proved effective and practical for protection of the hair from all types of dust, and they have the advantage of being easily replaceable as soon as they become soiled. The use of gloves has already been discussed; in the main, they failed to provide adequate protection for the hands under working conditions.

For eye-protection, a wide selection of goggles was provided. The chemical workers seemed to prefer wide-angle curved-front goggles with perforated metal sides. The operation of charging the reaction-kettles with halocrine and novol diamine required gas-tight goggles with water-troughs to prevent fogging, but some workers preferred a complete helmet furnished with fresh air by means of a pump. In the tablet division a light spectacle-type goggle with plastic sidescreens was found most acceptable, since our purpose was not to exclude dust entirely, but

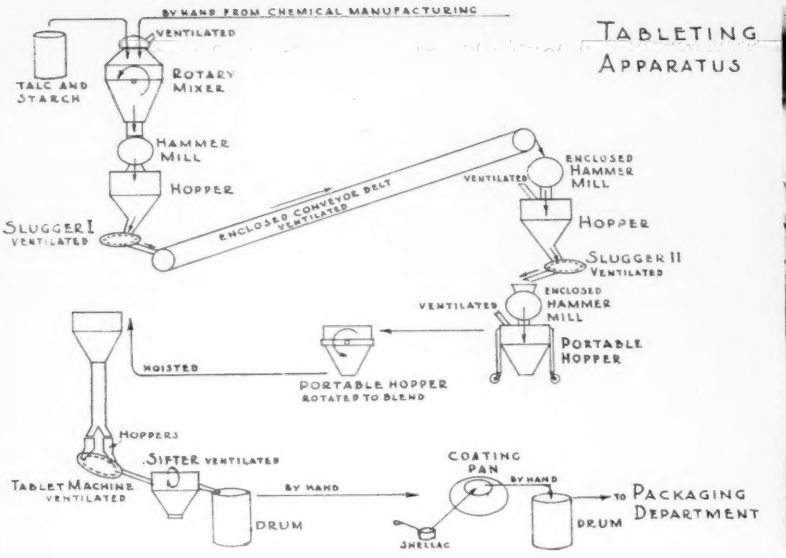


Fig. 3.
Flow sheet of tablet manufacturing operation

Fig. 4.
Slot exhaust fixtures on barrel and mixer

merely to reduce the amount reaching the eyes, and in particular to protect against flying particles which might be ejected from the slug and tablet machines.

M.S.A. "Dustfoe" respirators were most commonly used by the men in the tablet division, and by the chemical operators when they worked in the vicinity of spinning centrifuges or emptied trays of dry quinacrine. However, several other filter-type respirators were furnished to men whose facial contours did not fit the rather unyielding facepiece of the "dustfoe" model. It was found necessary to teach every new operator, especially in the tablet division, a certain rigid technique in the adjusting of the respirator. Experience showed that frequent shifting of the facepiece a few millimeters up or down, right or left, invariably caused a yellow ring to appear on the skin around the nose and mouth. Consequently, the men had to be taught that if they wished to remove their masks or shift them about frequently, they must remove them completely, go to the washroom and wash and dry both the rim of the mask and the face before replacing the mask. This rather arduous routine, as well as the invariable rule that the hand must never be allowed to touch the face or eyes without first being washed, was painfully taught to each new employee, by example and verbally, by the foreman of the department, an intelligent young man with many years' experience in the handling of powerful poisons.

Worker Morale

THE intense yellow staining of the skin, which was bound to occur despite all precautions, especially upon the hands, coupled with the acute discomfort which was visited for a few days upon those who failed to observe the necessary precautions, gave rise to a psychic hazard which required special attention. Rumors appeared from time to time among the workmen that the drug was a systemic poison, permanently injurious to health. The reasoning ran as follows: "Anything that is so powerful it will stain your skin so you can't wash it off must soak clear through your system and poison you. Soon I will be yellow clear through." Fears of this kind were freely expressed to me, and I found they could be easily allayed by pointing out known facts. The men all knew that each tablet contained 100 milligrams, and they knew that the amount of dust in the air had been measured from time to time. It was sufficient to show them how small an amount of quinacrine was in the air, and to tell them that our soldiers took two or more tablets a day for weeks or months, to convince them that no systemic poisoning could exist. It was also found advantageous to spend five minutes immediately following the pre-employment physical examination of these men to describe to them accurately the nature of the material they were to handle. They were frankly told that it was a powerful irritant to the eyes, nose, mouth and skin, and that it would produce conspicuous yellow stains which would not wash off. Then they were told that any operator could avoid irritation if he were skillful, careful and experienced. A few words concerning the vital importance of the tablets to the war effort then sufficed to send them out to the job with good morale.

Engineering Safeguards

TWO basic principles were followed in the design of the machinery of the tablet division: (1) To eliminate open handling of the drug, and (2) To enclose all dust-producing machine parts as completely as possible, keeping the enclosure under negative pressure of great enough magnitude so that the few openings which did exist in the system would be admitting air at a high velocity.

The only open handling required in the entire tablet division was the hand-scooping of quinacrine and excipients into the first mixer. As the table of air-samples shows, this was the most strongly contaminated point in the whole operation. The opening of the mixer was equipped with a removable fixture which draws air at high velocity into a slot along the upper edge of the opening (Fig. 4). A semicircular portable fixture with a curved slot was also provided for attachment to the drums from which the powders are scooped. After the mixer was filled, its opening was covered with a dust-tight lid, fastened on with bolts, and it was rotated on an axis until the powders were thoroughly mixed. This was a completely closed operation, and gave rise to no dust. The rotation was stopped with the tumbler in such a position that its lowermost portion could be attached by means of a dust-tight flexible connection directly to a closed ham-

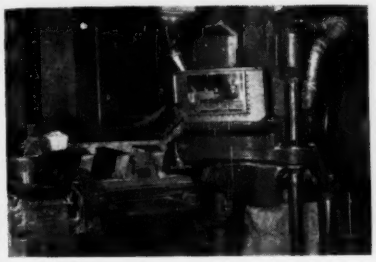


Fig. 5.
Exhaust shield on slug-forming machine; slugs pass to left into an enclosed hammer-mill

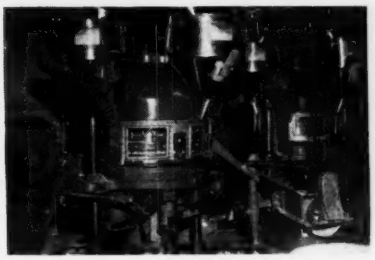


Fig. 6.
Exhausted shield on table machine; ventilator sifter in right foreground

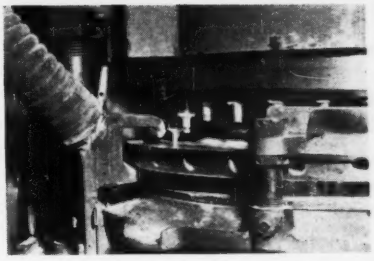


Fig. 7.
Local exhaust fixture on tablet machine opposite punches. Shield (Fig. 6) has been removed

mer mill, into which the powder dropped by gravity. The milled powder fell into a dust-tight hopper which was kept under negative pressure by a small connection to the general exhaust system. This hopper fed directly by gravity into the die-plate of the first slugger. The chief source of dust in the slugger was the dust thrown off the rotating die plate and the dust created each time a punch compressed the powder in one of the dies. Accordingly, sheet-metal hoods were designed to cover the die-plate around its whole circumference, except for small openings at the points where powder was fed in and slugs were ejected (Fig. 5). The hoods were exhausted by flexible connections to the general exhaust system.

Handling of the slugs was avoided by having them discharge directly into a small belt conveyor, completely enclosed and connected to the general exhaust system. This conveyor carried the slugs to the inlet of an enclosed hammer-mill permanently installed over a hopper which fed directly to the second slugger. This hopper was kept under slight negative pressure, and the slugger was protected by an exhausted hood exactly like that described. The slugs dropped from this second slugger into another dust-tight hammer-mill, from which the granulation fell through a flexible connection into one of a series of large portable hoppers made of sheet-metal. These hoppers were provided with an inlet at the top, an adjustable outlet at the bottom, and a small hose-connection at the top by means of which they were connected to the general exhaust system. All these openings could be closed with dust-tight covers.

The portable hoppers, after being filled with granulated material, were lifted with a small electric hoist into frames located over the tablet machines. Flexible hose-connections were attached to the hopper-outlet, and led down to the small hoppers of the tablet machines. By opening a gate, the granulation was allowed to run down the hose into the small hoppers, and thus to feed into the die-plate of the tablet machine. The tablet machine itself was equipped with hoods of sheet metal and transparent plastic similar to those used on the sluggers (Fig. 6); in addition, a special fixture just opposite the two points where the punches drive into the plates locally removed dust at this most important point of origin by means of high-velocity air streams (Fig. 7).

As the tablets rolled out of the machines, they were accompanied by a certain amount of dust, and had therefore to be sifted. This operation was mechanized by having them roll into small rotating barrels of wire mesh which sloped downward at a slight angle. These sifters were surrounded by a metal jacket which was also connected to the general exhaust system. From the sifters, the tablets rolled into drums, ready for transportation to the coating room. Thus a series of operations which, according to the ordinary practice of the trade, would require material to be handled in the open six or eight times was mechanized to the point where only one open handling was required.

All the machinery just described was ventilated by a single blower of the wet centrifugal type, having a capacity of 2000 c.f.m. This was attached through a cyclone dust collector to a manifold system with adjustable outlets for each machine. With all outlets open under operating conditions, the negative pressure in the main manifold duct was four inches of water. Sufficient filtered and heated outside air to balance the exhaust was introduced through a separate system.

As a final precaution, to prevent dust from broken tablets, spilled granulation, or other sources from being scuffed into the air, the tablet division was equipped with a portable vacuum cleaner, and one member of the working force was detailed solely to the task of picking up any stray dust which may appear on any of the working surfaces.

Summary

THE FINAL synthesis, purification, and manufacture into tablets of quinacrine dihydrochloride (atabrine), under wartime conditions, presented a problem in industrial hygiene because of the irritating nature of the drug.

2. Occupational disorders observed in 42 workmen over a period of eight months were found to consist solely of manifestations of local irritation of the mucous membranes and skin. In the order of frequency, these took the form of conjunctivitis, rhinitis, dermatitis and stomatitis. Keratitis, epistaxis, pharyngitis, tracheitis, bronchitis, asthma and dyspnea were also observed in a few cases. Preceding exposure, character, duration and treatment of these symptoms are described.

3. The industrial hygienic methods adopted to control this problem are discussed from the standpoint of (a) personal protective equipment, (b) worker morale, (c) engineering safeguards.

4. Despite an elaborate system of dust-control, which reduced air levels of quinacrine to 0.4 to 4.2 micrograms per liter, irritative symptoms persisted among the unskilled and undisciplined workers typical of the wartime emergency.

DR. FRED J. WAMPLER, Professor of Preventive and Industrial Medicine at the Medical College of Virginia, Richmond, resigned as of October 1, 1944, to become Medical Director of Rustless Iron & Steel Corporation, Baltimore. DR. WAMPLER is well known in the industrial medical field as an author, and as the Editor of and a contributor to "Principles and Practice of Industrial Medicine," published by Williams & Willkins, in 1943.

DR. PILGRIM

—*Continued from page 875.*

hint for the industrial physician, to whom is not unknown what might be designated "compensation fever." For the unabridged extends its definition: "hence, in general, one who shirks his duty by pretending illness or disability" . . . WAS interested to come upon the following in "Manual of Industrial Hygiene and Medical Service in War Industries": *"There has been too great a tendency for industrial hygiene physicians and engineers to gather at official conferences, association assemblies, and annual banquets of medical directors, and discourse at great length on what they are doing to protect the health of workers while in reality their programs fall far short of these objectives. Sometimes the impression is quite evident that these mutual admiration contests are a sort of defense mechanism for what is being left undone. In too many plant medical departments, the primary and often the sole function is to provide reparative service for injuries, and the medical department owes its existence to the fact that the plant is a self-insurer." Conclusions of this kind are the errors into which those fall who learn by hearsay what industrial medicine is thought by some to have been, without having the knowledge that is part of the experience of those who, being in it, are correctly aware of what it was. And such statements as this confirm the persistence of untruths and half truths, such, for example, as the long-trite cliche that industrial medicine was always curative, never preventive. Thirty years ago the A.A.I.P. & S. incorporated in its objectives (see page 8): "to develop methods adapted to the conservation of health among workers . . . ," and wherever industrial medicine is, there it is true of "industrial hygiene physicians and engineers," as to all and each, that "he procureth health where there is none, and continueth and increaseth it where it is." That there are many smaller concerns with only emergency medical service, or no service, is not because the industrial medical and hygiene group could do, and are not doing, what is "being left undone." If *they could, they would.* But more of this anon. . . .

*Prepared by the Division of Industrial Hygiene, National Institute of Health, U. S. Public Health Service. Published by W. B. Saunders Company, 1943.

American Industrial Hygiene Association
News of Local Sections

Chicago Section

THE first meeting of the year 1944-45 of the Chicago Section of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION was held September 28, with 74 members and guests present. Some deviation has been made from the program style of previous years in that two members of the local section have been asked to talk at each meeting to cover recent literature pertaining to industrial hygiene. The medical aspects are to be covered by a physician and the engineering and chemical topics by a technical industrial hygienist. These speakers will share about 15 minutes of the program time at the beginning of each meeting. The first two members who spoke at this first meeting were DR. EDWARD E. DART, of Dodge Chicago Plant, and MR. WARREN A. COOK, of Zurich Insurance Company.

The main speaker of the evening was DR. NORBERT ENZER, of Milwaukee, Wisconsin. DR. ENZER is a pathologist, greatly interested in silicosis, and has done considerable work on this subject during the past few years. Some of his concepts are somewhat different from the classical ideas as expounded by GARDNER and others. DR. ENZER exhibited colored slides of lung sections showing the typical nodular fibrotic conditions, and of x-ray films. The comparison was drawn between a group of 15 welders and 15 foundry workers, both having markings characteristic of second stage silicosis. He went on to show, by means of a number of tests, that there is a great deal of difference between body functions and efficiency of these two groups. Some of these tests were tapping rate, breath holding, strength tests of various muscle groups, work capacity and the flicker fusion test. Of the group of foundry workers that he studied, three were completely disabled and showed nearly all of the typical silicosis symptoms. One member of this group was partially disabled but still able to work. The other six were apparently in a good state of health, although still showing lung shadows on an x-ray film. The 15 welders, all comparatively young men, had been working for periods upward of six years and were in apparently good health.

The tests mentioned were performed on all of these 25 individuals several times, and the scores made on these tests were weighed and scored according to how much they varied from normal individuals taking the same tests. The total scores of each individual showed very conclusively that those people who complained of all the symptoms of silicosis varied considerably from the extremes of normal persons taking the same tests. As a group, the welders did not vary considerably from a normal group. Although the x-ray chest films of these two groups did not show large differences, these tests proved quite conclusively that there were large differences in body functions. DR. ENZER explained this by four slides of sections of lung tissue that had been stained with Prussian Blue for iron. Nearly all of the group of welders showed large amounts of iron pigment in the lung. He stated that he thought this material caused the shadows on the x-ray films. The iron in the lungs of this group of welders did not seem to cause a fibrotic condition in the lung, but this was not evident without staining the lung section. He termed this condition siderosis.

WANTED: Industrial Hygienist to conduct surveys of industrial plants for large insurance company with complete laboratory facilities and field testing equipment. This is an excellent opportunity for a permanent, *not a war-period*, position. State age, family status, education, experience, qualifications, and minimum salary. Address INDUSTRIAL MEDICINE, 605 N. Michigan Ave., Chicago 11.

Michigan Section

THE Michigan Industrial Hygiene Society is one of the sponsors of a three-day meeting to be held November 1 and 2, in Detroit, under the auspices of the Detroit Safety Council to cover the principal occupational disease hazards and their control. On the program:

"Vapor Degreaser Operation"—FRANK A. PATTY, General Motors Corporation, Detroit.

"Carbon Monoxide Exposures"—WILLIAM FREDRICK, PH.D., Detroit Bureau of Industrial Hygiene.

"Fluorides from Welding Rods, Magnesium Foundry Operations and other Industrial Exposures"—GORDON P. HARROLD, PH.D., Chrysler Corporation, Detroit.

"Silicosis Prevention"—H. H. SCHRENK, PH.D., U. S. Bureau of Mines, Pittsburgh.

"Lead Poisoning Control"—WARREN A. COOK, Zurich Insurance Companies, Chicago.

"Ventilation"—WILLIAM WITHERIDGE, Detroit Bureau of Industrial Hygiene.

"Organic Chemicals"—DON D. IRISH, PH.D., Dow Chemical Company, Midland, Michigan.

St. Louis Section

THE first meeting of the Industrial Hygiene Society of Greater St. Louis is to be addressed by WARREN A. COOK, of the Zurich Insurance Companies, on October 25, 1944. MR. COOK'S subject will be "Value of Industrial Hygiene Postwar on the Basis of Accomplishments in the War Effort."

New England Section

AN ALL-DAY meeting is to be held in Boston in December for discussion of recent contributions in industrial hygiene by members of this local section. This will be another of the valuable series of meetings following the pattern of previous gatherings of this section.

THE NINTH Annual Meeting of members of Industrial Hygiene Foundation, an association of industries for the maintenance of healthful working conditions, will be held at Mellon Institute, Pittsburgh, the Foundation's headquarters, on November 15 and 16.